NASA Instrument Capability Study

Summary and Recommendations

Agenda

- Study Overview and Implementation
- Summary of Data Analysis
- Findings and Recommendations

Study Background

- Numerous NASA projects have had difficulties in developing science instruments for application to their missions, affecting projects across the NASA mission directorates
- NASA's Office of Chief Engineer (OCE) chartered a comprehensive cross-cutting study to evaluate instrument development capability across the Agency
- The National Oceanic and Atmospheric Administration (NOAA) and the Department of Defense (DoD) also participated in this Study with NASA.

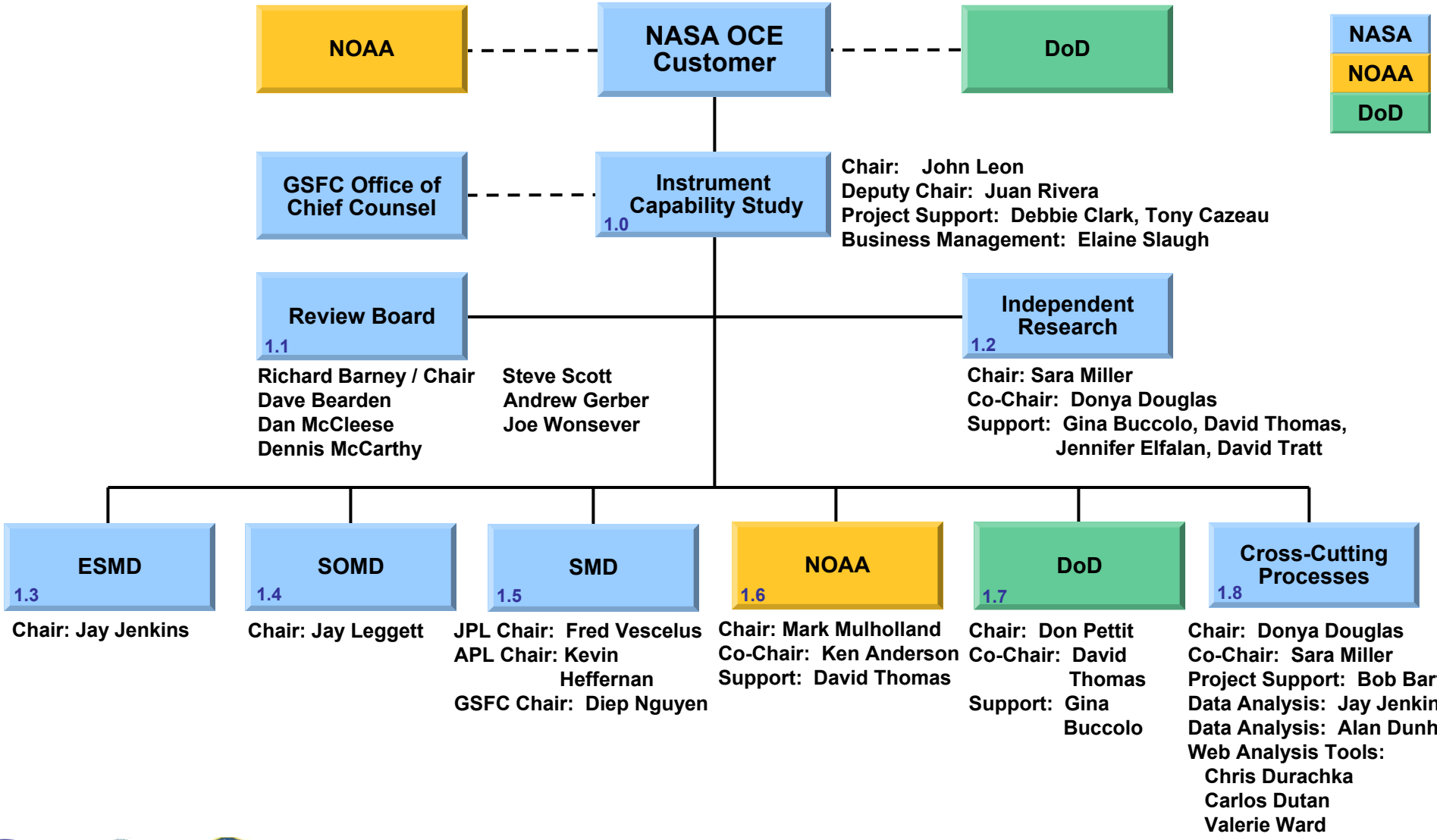
Study Charter

- Determine if NASA instrument developments are facing:
  - Challenges that impact the capability to design and build quality instruments, or…
  - Flaws in the acquisition strategy evidenced by schedule delays, cost overruns, and increased technical risk via design deficiencies
- Determine if occurrences seen recently are coincident, but isolated cases
- If there are, indeed, generic issues that are causing such degradation, seek options for solutions to recover such capability

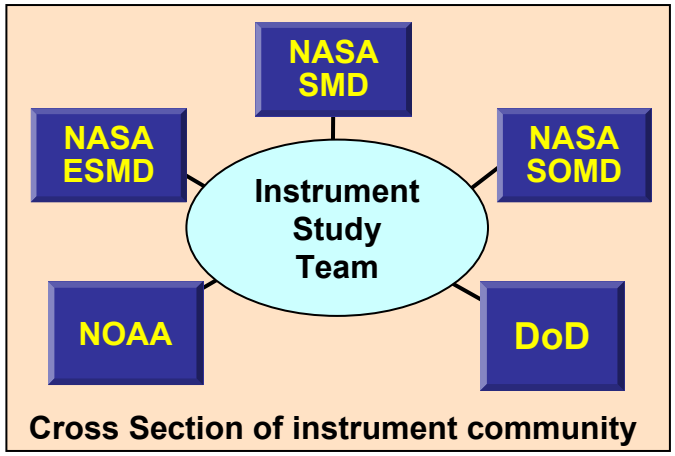
Achieving Study Objectives

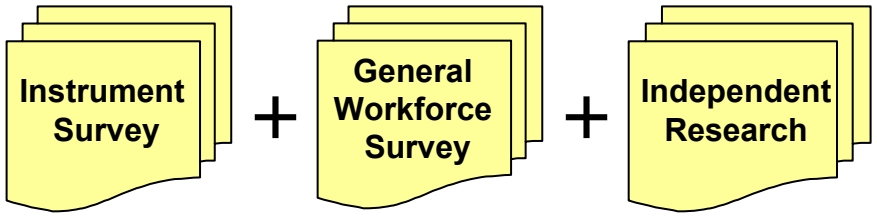
- **OCE Objective 1:** Obtain macro-level understanding of potential instrument development problems (not root cause analysis)
- **OCE Objective 2:** Determine factors that impact primary success indicators
- **OCE Objective 3:** Determine factors that impact instrument development processes
- **Team Objective 4:** Identify potential issues for high risk or high complexity instrument developments
- **Team Objective 5:** Determine overarching Study Themes

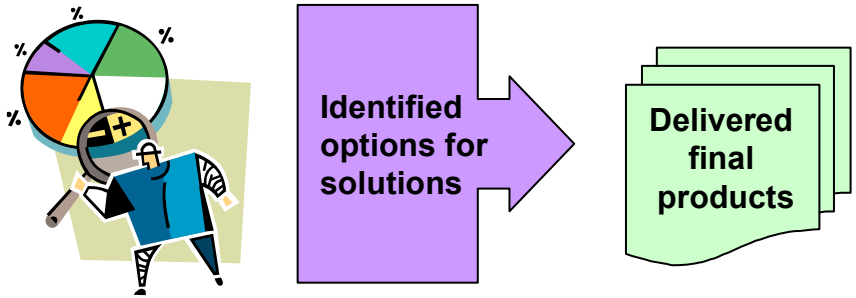
Team Structure – Top Level (distributed, virtual team)



Study Implementation



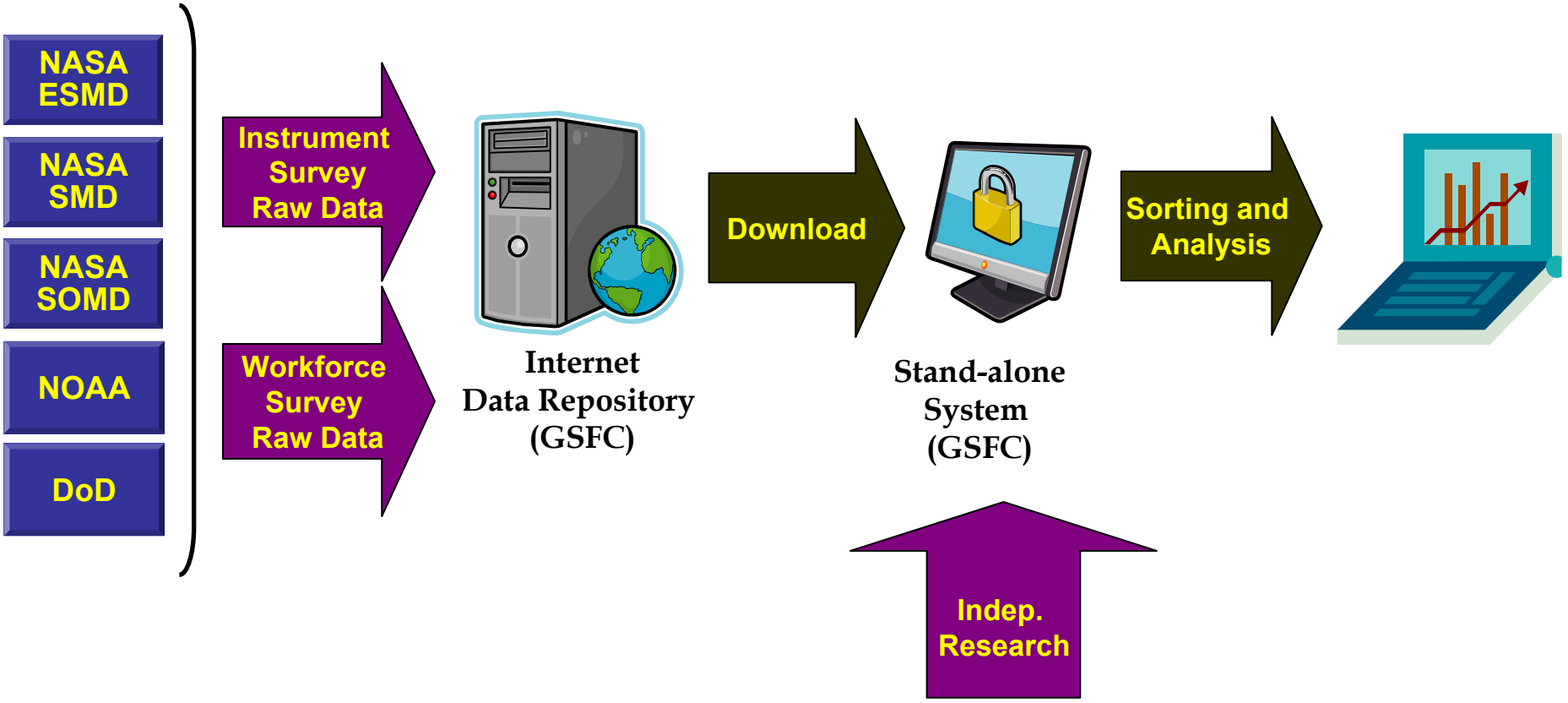




- Instrument Study team internal and external to NASA
- Implemented instrument (41) and general workforce (164) surveys that cut across key aspects of instrument development
- Conducted independent research (~1,000 database entries)
- Held industry workshop June 13, 2008
- Analyzed data and identified five overarching Study themes
- Held NASA, NOAA, and DoD focus groups
- Developed five Study findings and associated recommendations

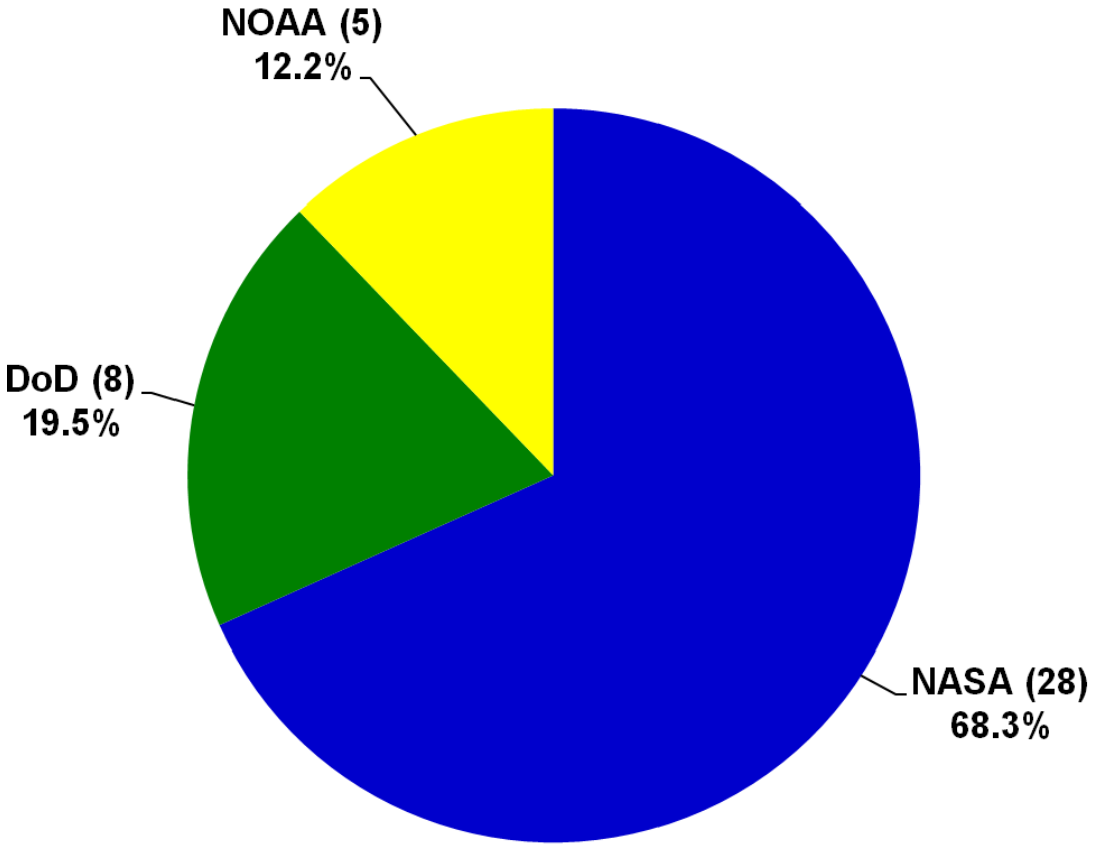
Survey Data Flow

Data Integrity
Strict confidentiality maintained throughout study process
Reviewed and approved by GSFC Legal



Summary of Data Analysis

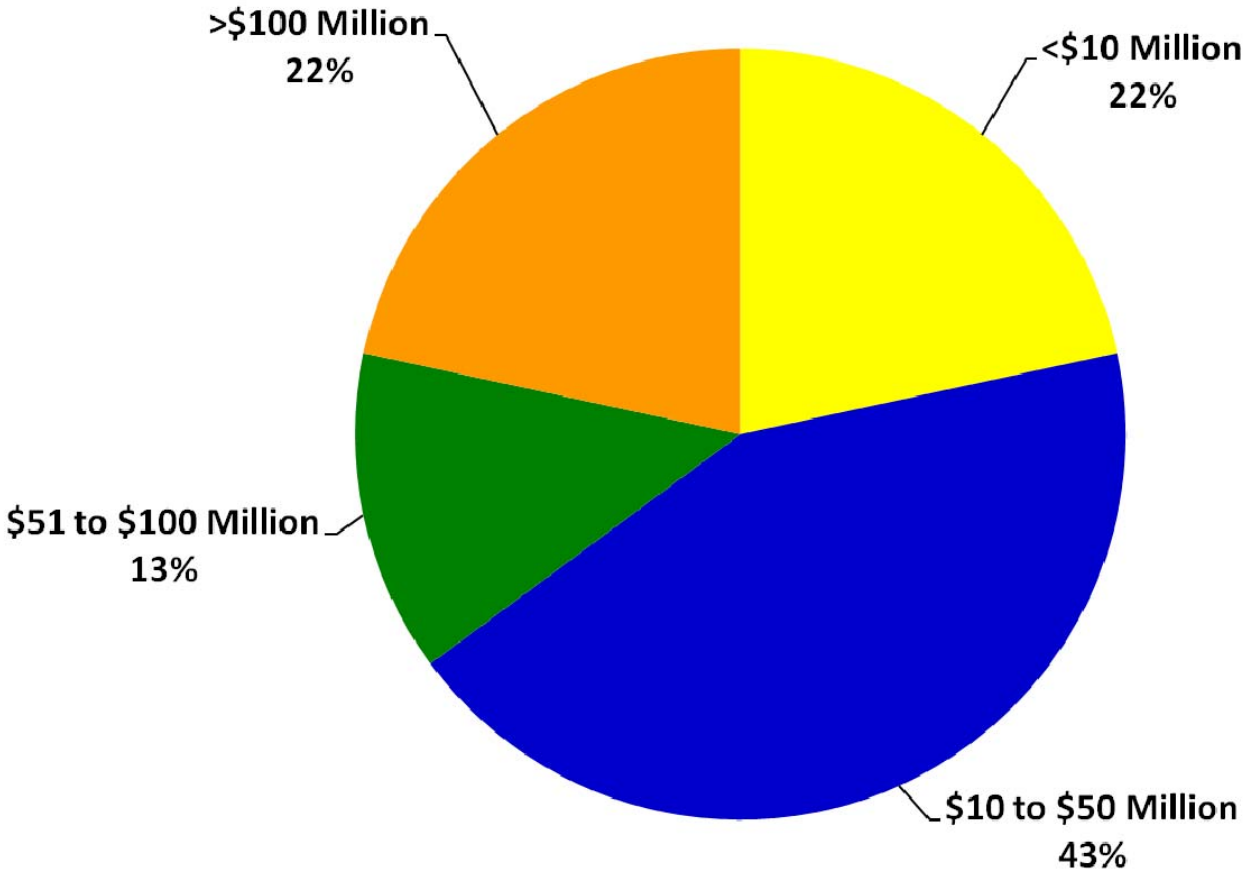
Instrument Participation
By Sponsor



41 Instruments

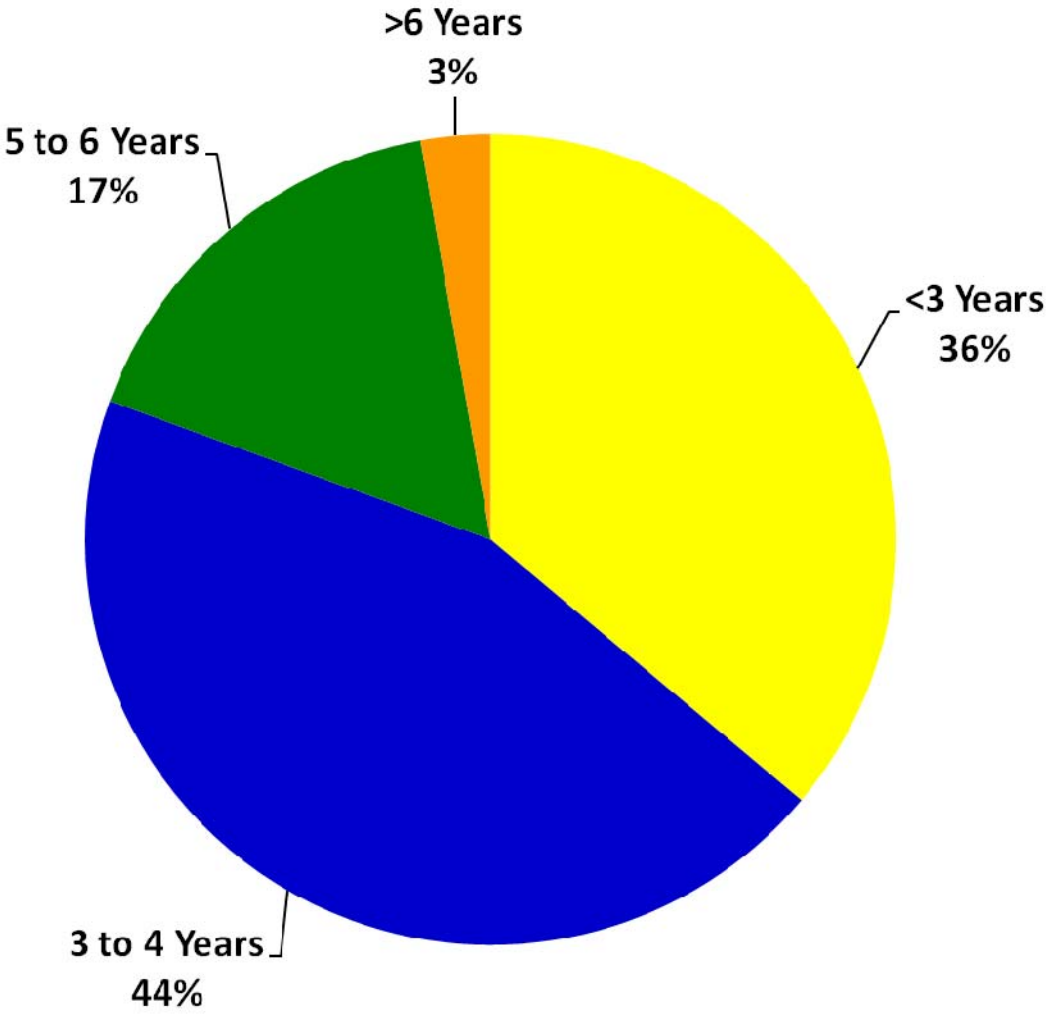
Diverse set across Government, Industry, and University developers

Instrument Budget
At Contract Award/Proposal Selection



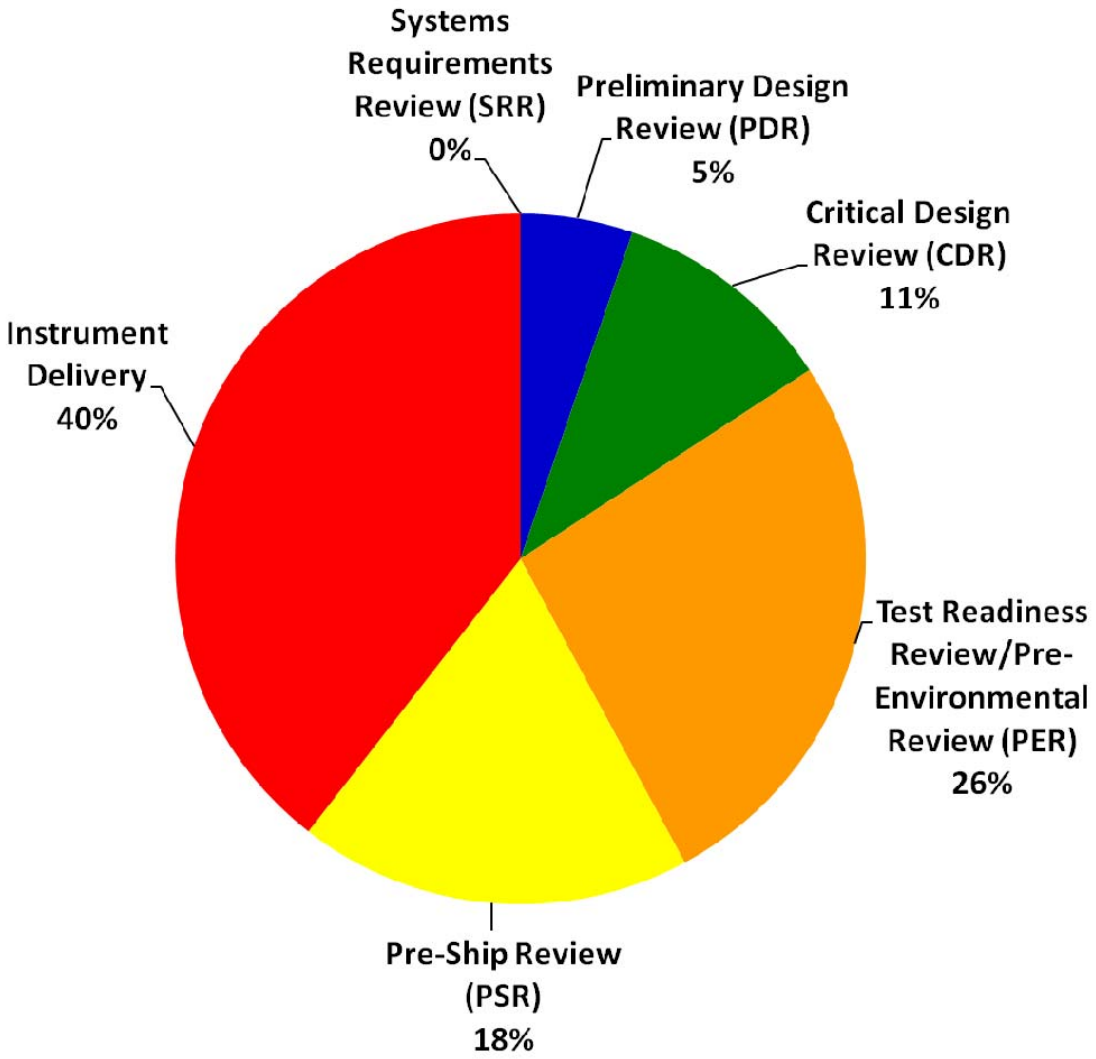
~65% of the instruments had a budget of ≤$50M at contract award or proposal selection.

Instrument Schedule
At Contract Award/Proposal Selection



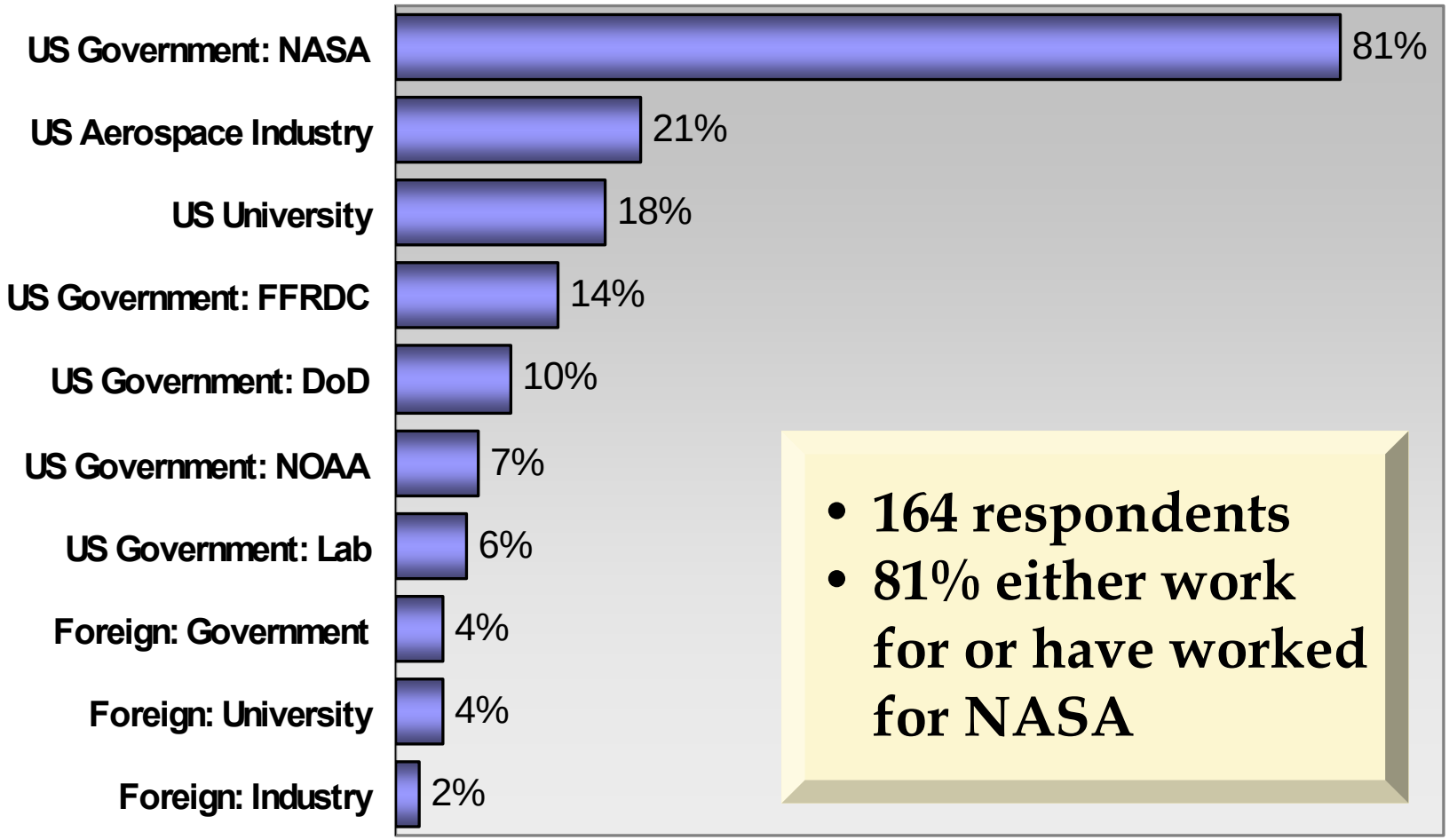
~80% of the instruments had a schedule duration of ≤4 years at contract award or proposal selection.

Most Recent Review
Completed by Instrument Team



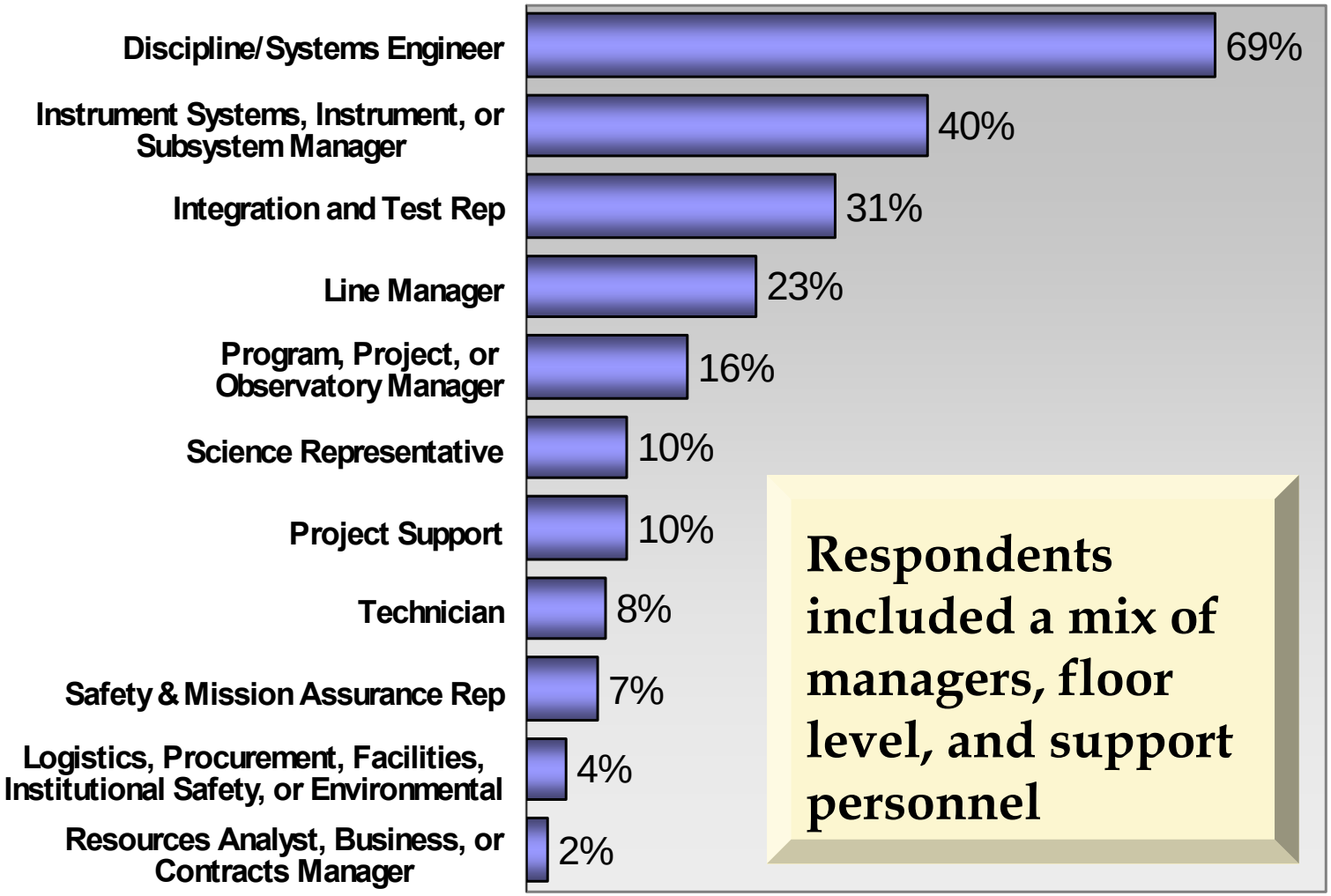
Most of the instruments were in Phases A through D at the time of the survey.

General Workforce Participation
By Organization



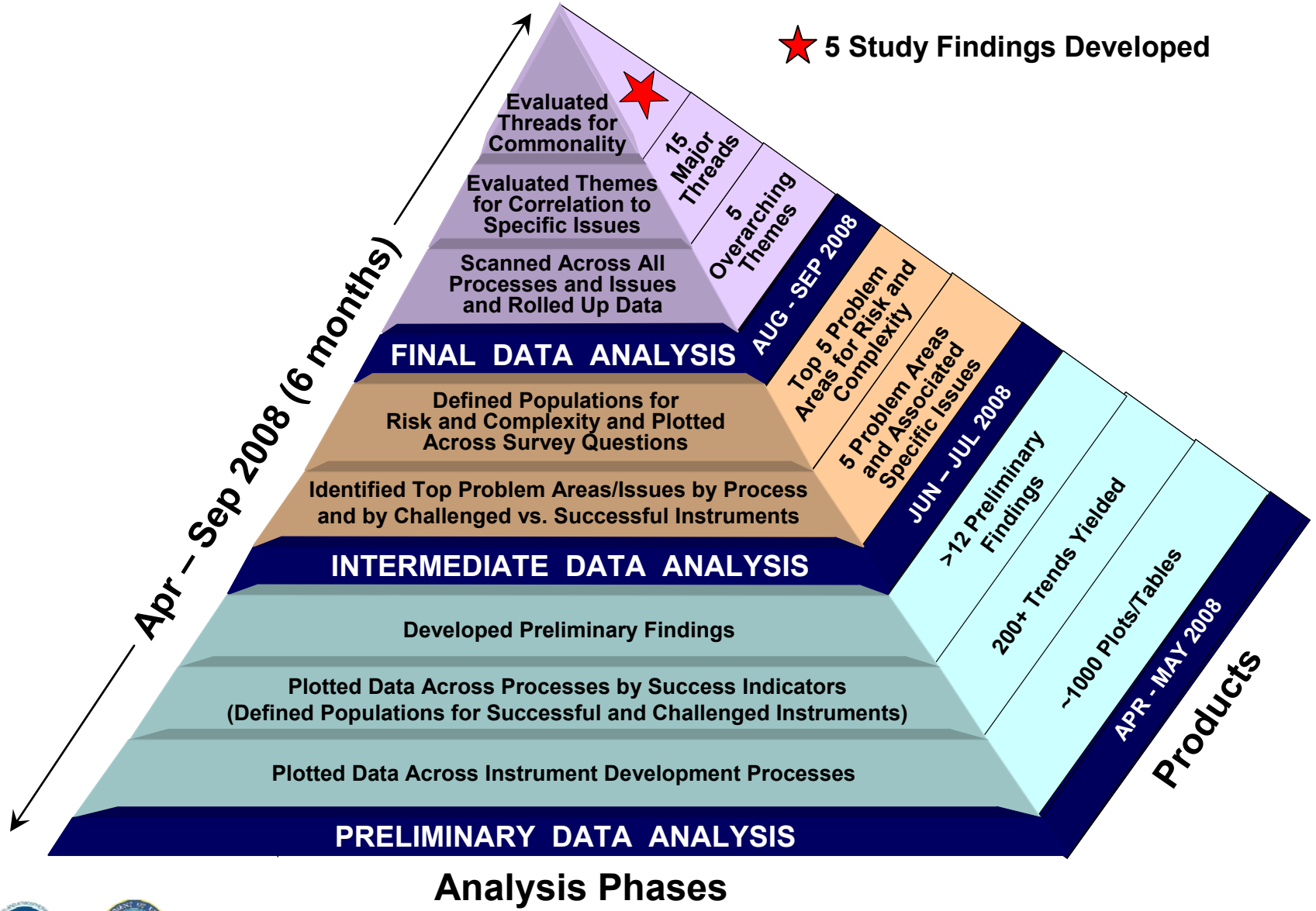
Includes all past and present organizations for which respondents worked.

General Workforce Survey
By Role



Includes all past and present positions held by each respondent.

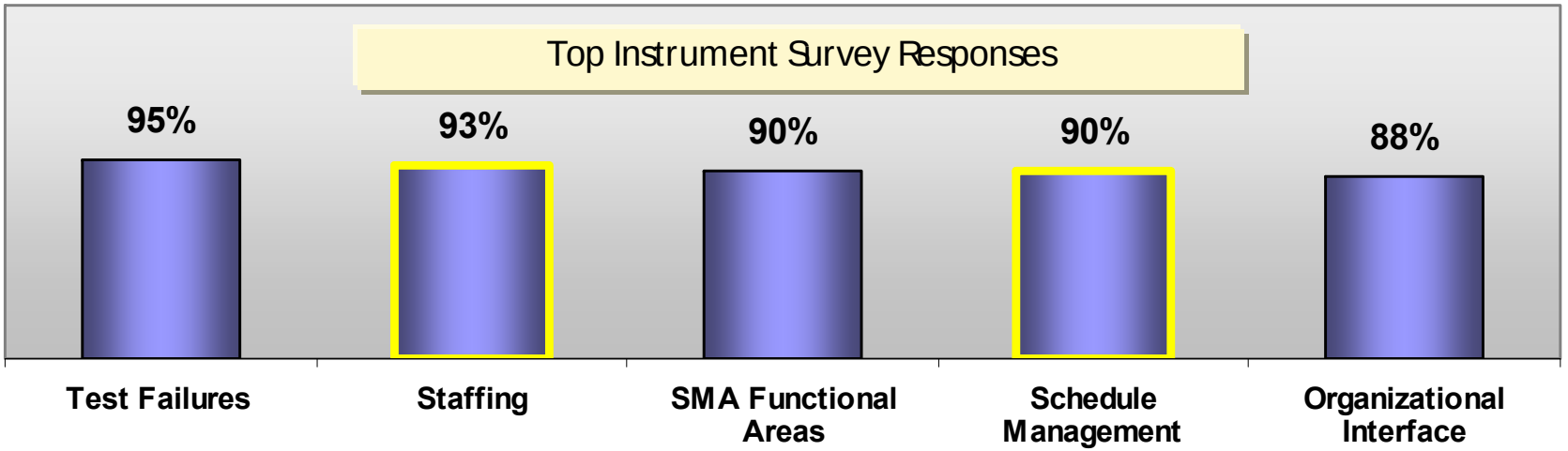
Data Analysis Process

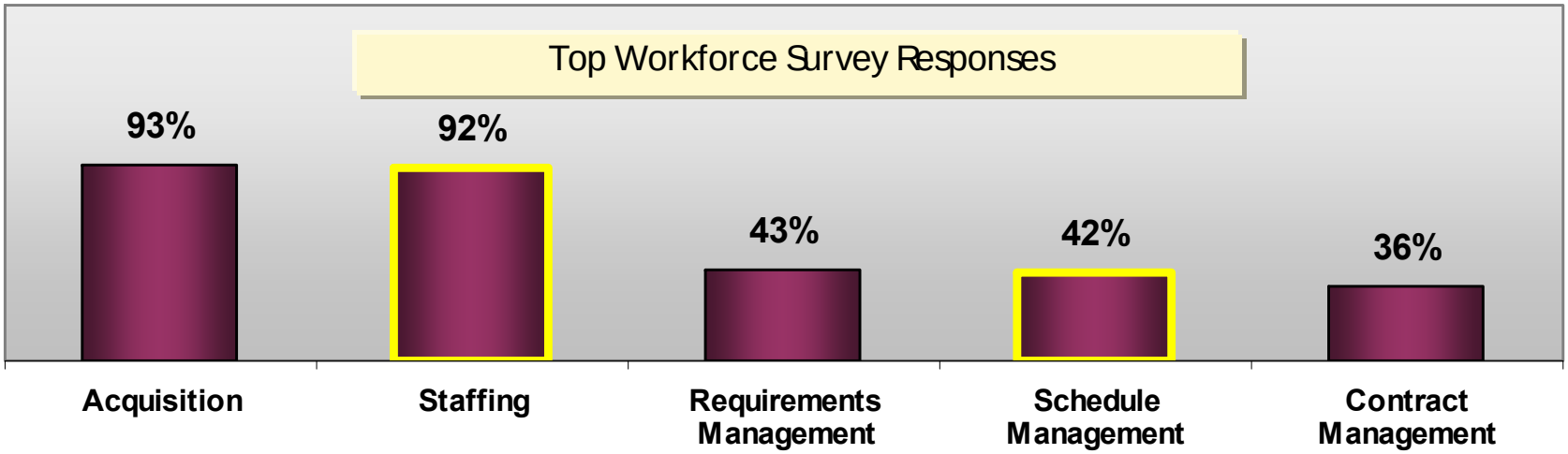


Stepping Through the Data

- **Cross-Cutting Problem Areas**
- Challenged vs. Successful
- Higher Risk vs. Lower Risk
- More Complex vs. Less Complex
- Over-Arching Study Themes
- Findings and Recommendations

Top 5 Cross-Cutting Problem Areas
As Reported by Instruments & General Workforce





Stepping Through the Data

- Cross-Cutting Problem Areas
- **Challenged vs. Successful**
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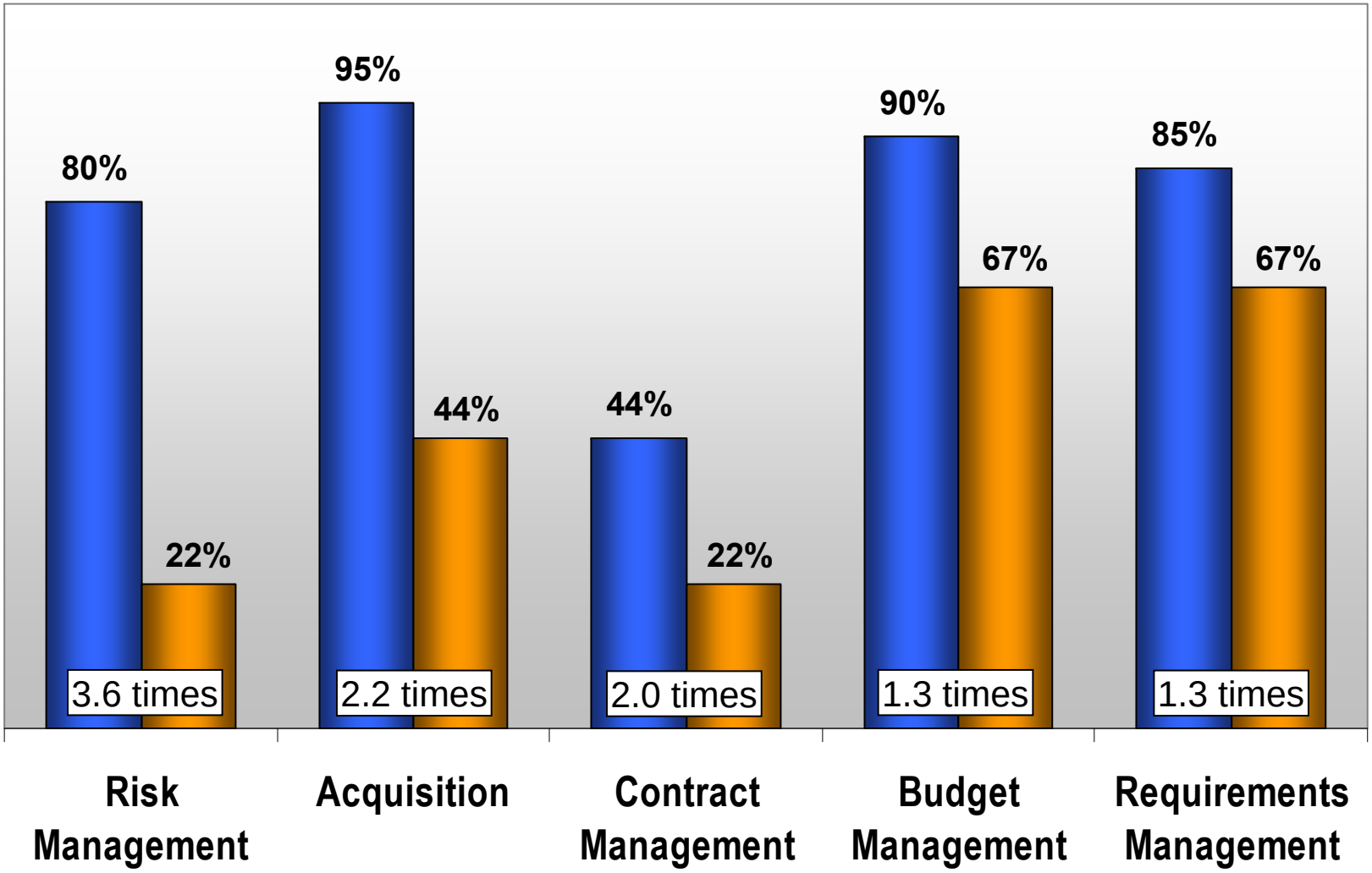
Top 5 Cross-Cutting Problem Areas
By Correlation with Cost and Schedule Performance



Stepping Through the Data

- Cross-Cutting Problem Areas
- Challenged vs. Successful
- **Higher Risk vs. Lower Risk**
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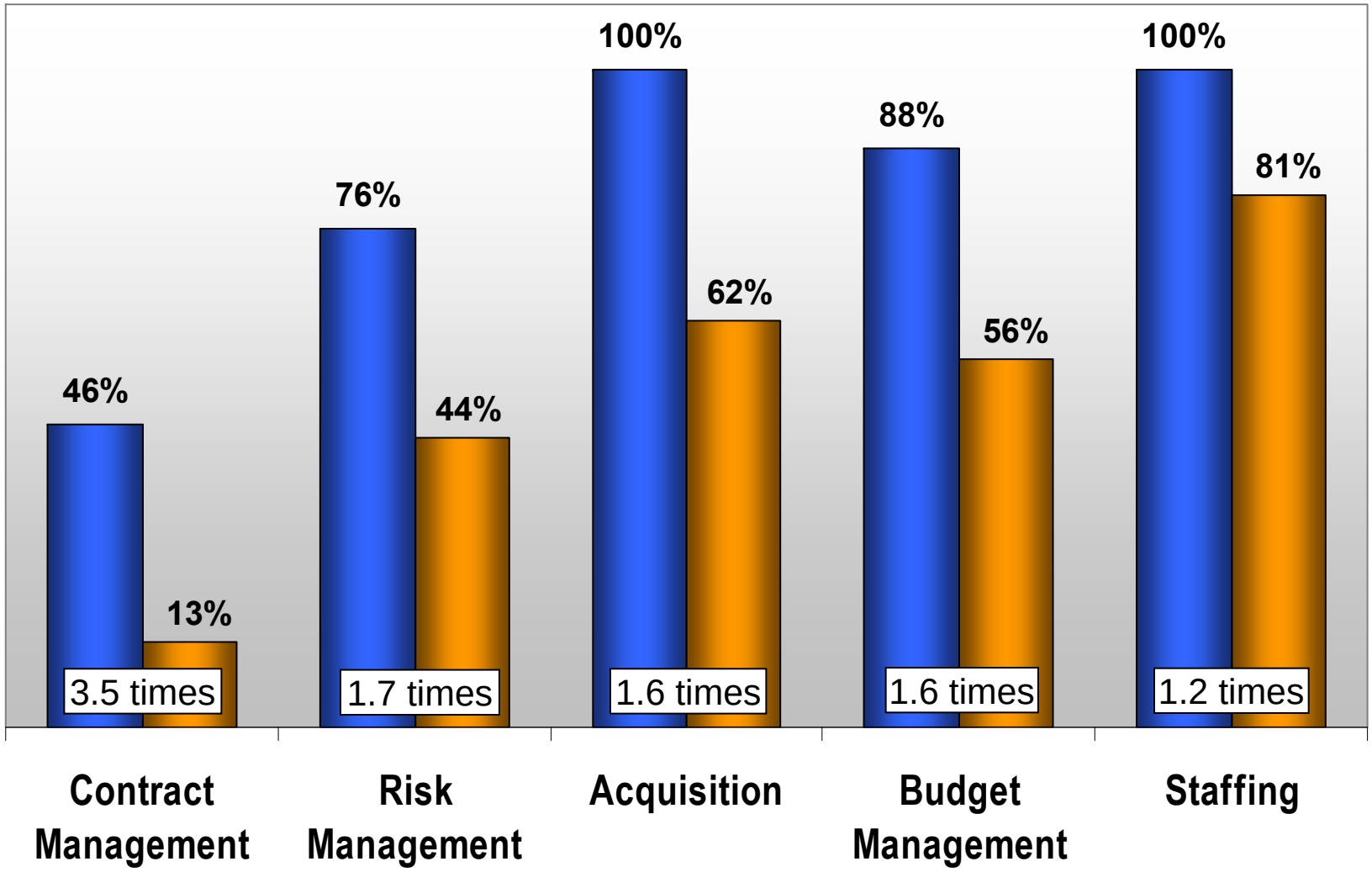
Top 5 Cross-Cutting Problem Areas
By Correlation with Risk Posture



Stepping Through the Data

- Cross-Cutting Problem Areas
- Challenged vs. Successful
- Higher Risk vs. Lower Risk
- **More Complex vs. Less Complex**
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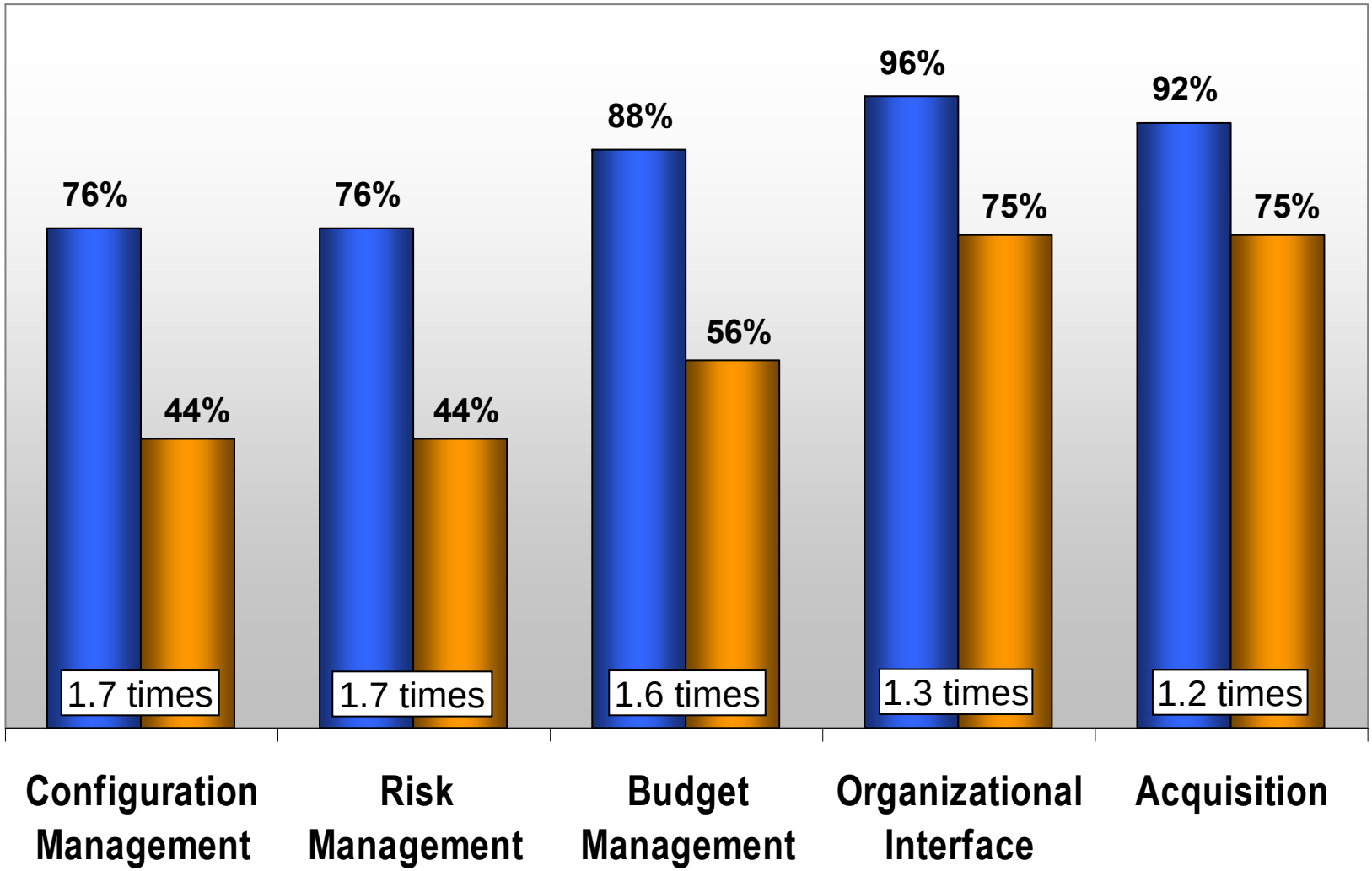
- Findings and Recommendations

Top 5 Cross-Cutting Problem Areas
By Correlation with Complexity



Stepping Through the Data

- Cross-Cutting Problem Areas
- Challenged vs. Successful
- Higher Risk vs. Lower Risk
- More Complex vs. Less Complex
- **Over-Arching Study Themes**
- Findings and Recommendations

Over-Arching Study Themes

- Staffing (ST)
- Acquisition (AQ)
- Testing Issues (TI)
- Systems Engineering (SE)
- Instrument Management (IM)

GWS	General Workforce Survey
IS	Instrument Survey
NCN	No correlation noted
N/A	Not applicable

Study Themes and Threads
Looking within each Study Theme

- **STAFFING (ST)**
  - Instrument Leadership Issues
  - Instrument Teams are Understaffed
  - Difficulty Acquiring Critical Skills
- **ACQUISITION (AQ)**
  - Insufficient Resources to Successfully Develop Instruments
  - Supply Chain Issues
- **TESTING ISSUES (TI)**
  - Lack of Sufficient Cost and Schedule Reserves to Account for Issues During Testing
- **SYSTEMS ENGINEERING (SE)**
  - Requirements Management Problems
  - Requirements Formulation Issues
  - Issues with Requirements Changes
  - Risk Management Issues
  - Effectiveness of Reviews
- **INSTRUMENT MANAGEMENT (IM)**
  - Issues with Instrument Reserves
  - External Factors
  - Issues with Lines of Communication/Authority
  - Issues with Schedule/Budget Management

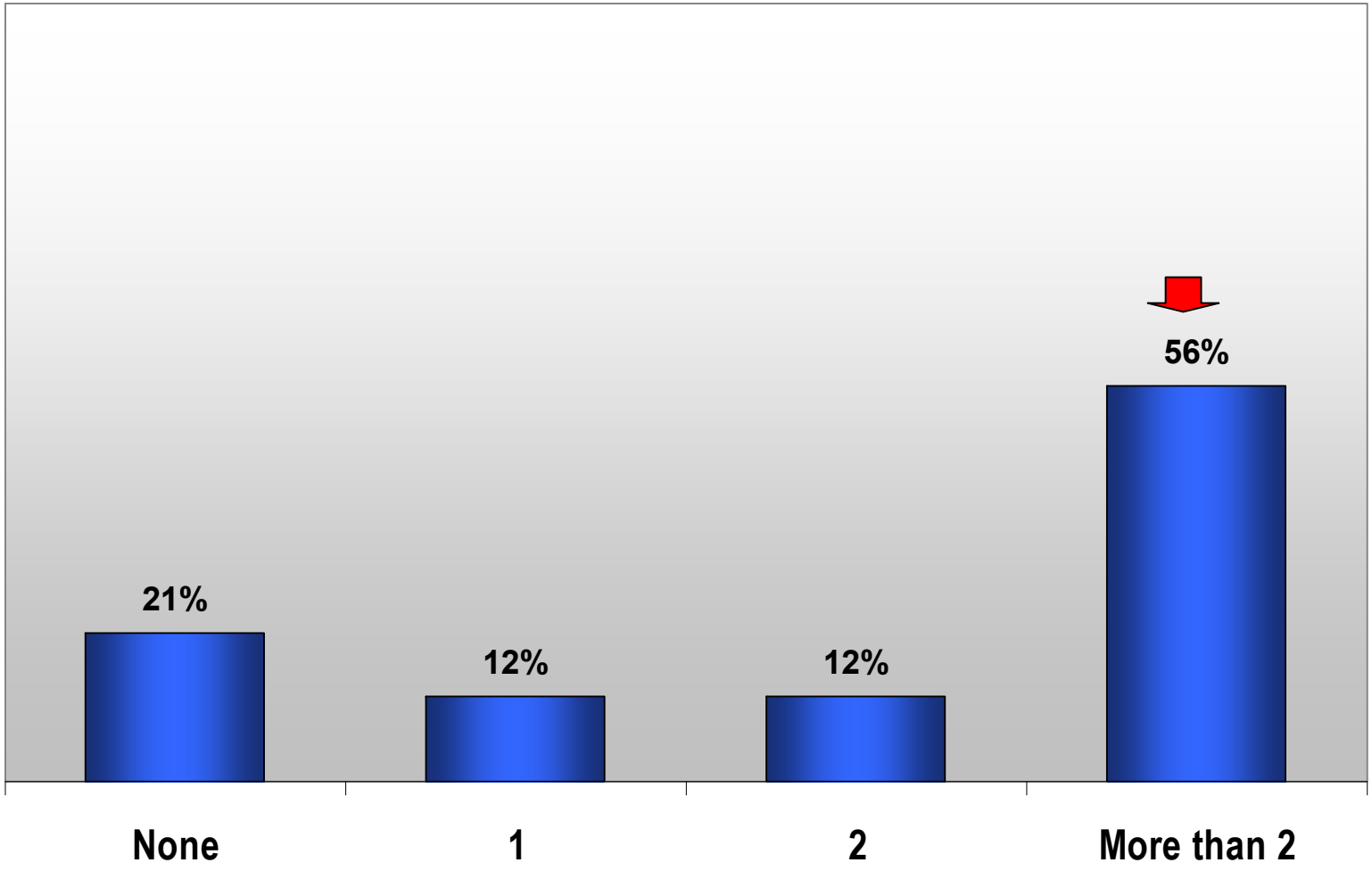
Staffing Theme

- Instrument Leadership Issues
- Instrument Teams are Understaffed
- Difficulty Acquiring Critical Skills

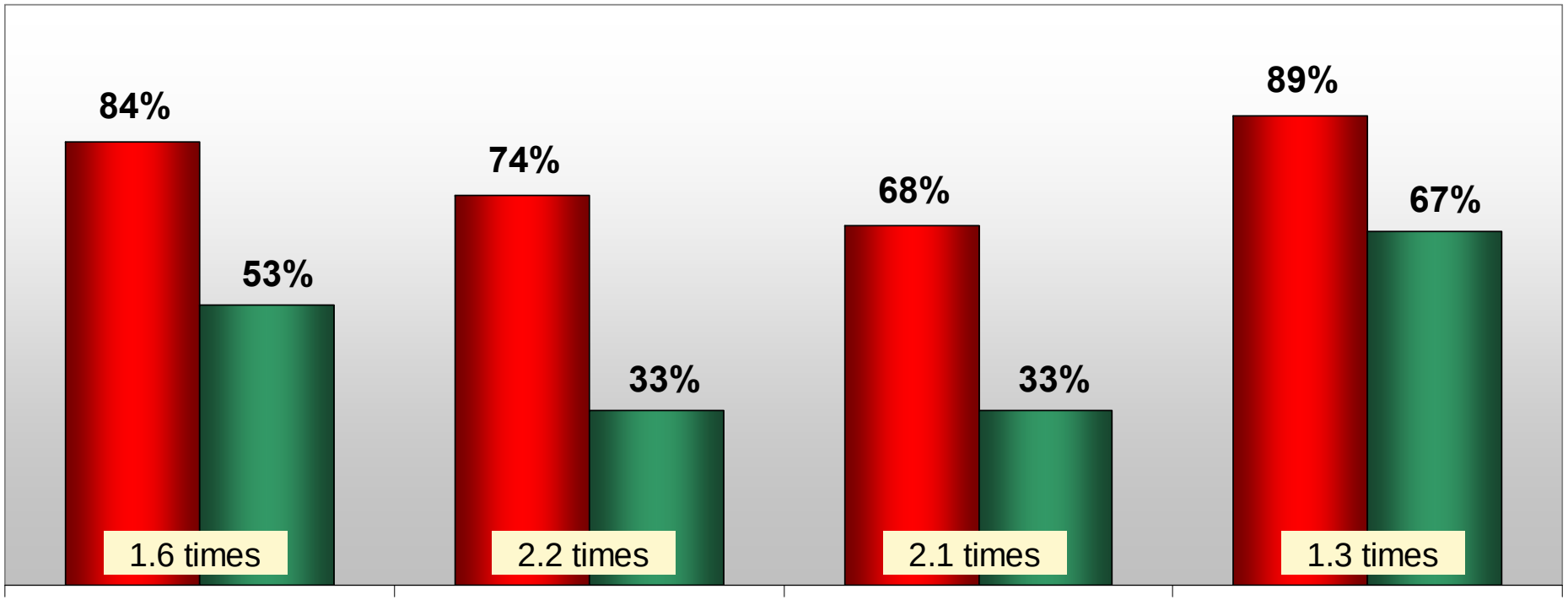
Staffing Thread #1: Leadership

ST-1 Thread: Instrument Leadership Issues			
Area	**Issue**	**Correlation**	
		≥25% Cost Overrun	**≥5 Months Schedule Delay**
Expertise/Experience	Inexperienced leadership (49%-GWS)	N/A	N/A
Expertise/Experience	Difficulty in finding expertise or experience (61%-IS, 64%-GWS)	1.7x	1.6x
Team Turnover	>2 changes in key leadership positions (56%-IS)	1.6x	2.2x

ST-1 Thread:
Changes in Leadership Positions



ST-1 Thread: Changes in Leadership Positions vs. Success Indicators



Theme: Staffing

Thread	Supporting Information
Instrument Leadership Issues	• The major issues noted during the MIB include: … and project leadership deficiencies introduced sufficient risk to compromise mission success, to the point of mission failure.[1] • The MIB identified the lack of training and experience of the design team as one of the root causes of the mishap. [2] • 69% of the ≥$10M instruments had >2 changes in key leadership positions vs. only 13% of the <$10M instruments, 50% of whom experienced no change in leadership. [plots]
Instrument Teams are Understaffed	• Additionally, according to the Office of Personnel Management, 60.8% of the full-time permanent federal workforce (as of October 2006) will be eligible to retire by the year 2016. [3]
Difficulty Acquiring Critical Skills	• The pipeline of science and engineering talent is shrinking at the same time that the demand is increasing in the private sector. [4, 5, 6]

Staffing Thread #2: Understaffing

ST-2 Thread: Instrument Teams are Understaffed			
Area	**Issue**	**Correlation**	
		≥25% Cost Overrun	**≥5 Months Schedule Delay**
Expertise/ Experience	Team members supporting multiple projects (50%-IS, 59%-GWS)	NCN	NCN
Staffing Levels	Project teams understaffed (45%-IS, 38%-GWS)	1.4x	1.2x
Team Turnover	Attrition (40%-IS)	1.1x	1.5x
Project Support	Configuration (54%-IS), risk (>50%-IS), schedule (50%-IS), and budget (42%-IS) management require more support	1.1x – 1.6x	1.2x – 1.8x

Staffing Thread #3: Critical Skills

ST-3 Thread: Difficulty Acquiring Critical Skills			
Area	**Issue**	**Correlation**	
		≥25% Cost Overrun	**≥5 Months Schedule Delay**
Expertise/Experience	Critical knowledge limited to a few individuals (68%-IS)	1.5x	2.2x
Expertise/Experience	Difficulty finding expertise (61%-IS, 64%-GWS)	1.7x	1.6x
Staffing Level	Safety & Mission Assurance Personnel availability/expertise (47%-IS)	1.2x	1.4x

Acquisition Theme

- Insufficient Resources to Successfully Develop Instruments
- Supply Chain Issues

Acquisition Thread #1: Insufficient Resources

AQ-1 Thread: Insufficient Resources to Successfully Develop Instruments			
Area	**Issue**	**Correlation**	
		≥25% Cost Overrun	**≥5 Months Schedule Delay**
Optimistic Budget or Schedule Estimates	Optimistic/Unrealistic initial budget (63%-IS, 68%-GWS) and schedule (59%-IS, 68%-GWS) estimates	2.7x	2.7x
	Challenged instruments more likely to report this as a problem (85%-budget, 75%-schedule)	7.7x more likely than the successful instruments (budget); 6.8x more likely than the successful instruments (schedule)	
Insufficient Allocated Budget or Schedule	Insufficient cost cap (32%-IS, 60%-GWS) and allocated schedule (44%-IS, 62%-GWS)	1.4x	1.5x
	Challenged instruments more likely to report this as a problem (40%-budget, 60%-schedule)	3.6x	6.8x

Acquisition Thread #2: Supply Chain

AQ-2 Thread: Supply Chain Issues			
Area	**Issue**	**Correlation**	
		≥25% Cost Overrun	**≥5 Months Schedule Delay**
Procurement	Parts, subsystems, or instrument level procurement issues (49%-IS)	1.3x	2.3x
	80% of the challenged instruments reported this as a problem	3.6x more likely than the successful instruments	
Suppliers	Component suppliers experienced cost growth (51%-IS)	1.6x	2.6x

Testing Issues Theme

- Lack of Sufficient Cost and Schedule Reserves to Account for Issues During Testing

Testing Thread #1: Test Issues

TI-1 Thread: Lack of Sufficient Cost and Schedule Reserves to Account for Issues During Testing			
Area	**Issue**	**Correlation**	
		≥25% Cost Overrun	**≥5 Months Schedule Delay**
Planning	Requirements were unverifiable (35%-IS)	1.3x	1.2x
Test Implementation	Testing took longer than anticipated (46%-IS)	1.8x	1.6x
Test Failures	Aggressive schedule contributed to test failures (45%-IS)	1.2x	1.4x
Cost/Schedule Growth During Testing	Test failures caused schedule delays (70%-IS)	1.6x	1.6x
	Workmanship or technical problems caused schedule delays (76%-IS) Note: 100% of the instruments that did not have an ETU had workmanship problems	1.6x	3.0x
	Problems with GSE or special test equipment caused schedule delays (41%-IS)	1.5x	2.0x

Systems Engineering Theme

- Requirements Management Problems
- Requirements Formulation Issues
- Issues with Requirements Changes
- Risk Management Issues
- Effectiveness of Reviews

Systems Engineering Thread #1: Requirements Management

SE-1 Thread: Requirements Management Problems			
Area	**Issue**	**Correlation**	
		≥25% Cost Overrun	**≥5 Months Schedule Delay**
Requirements Management	74% of the instruments that reported requirements management problems had design deficiencies. Instruments that did not report this problem did not have design deficiencies (0%).	1.7x	NCN
	Requirements or specifications were not clearly communicated (29%-IS)	NCN	1.2x
Requirements Changes	Work proceeding at risk ahead of change/waiver approval (38%-IS)	NCN	1.3x
	Implementation of changes was not timely (32%-IS)	1.5x	1.6x

Systems Engineering Thread #2: Requirements Formulation

SE-2 Thread: Requirements Formulation Issues			
Area	**Issue**	**Correlation**	
		≥25% Cost Overrun	**≥5 Months Schedule Delay**
Requirements Management	Insufficient traceability (41%-IS)	1.4x	1.9x
	50% of the challenged instruments reported this as a problem	None of the successful instruments reported this	
Requirements Management	Goals or desires were stated as requirements (38%-IS)	1.2x	1.5x
Requirements Management	Requirements were too complex (35%-IS)	1.6x	2.0x
	50% of the challenged instruments reported this as a problem	None of the successful instruments reported this	
Requirements Management	Requirements were unverifiable (35%-IS)	1.3x	1.2x
	40% of the challenged instruments reported this as a problem	1.8x more likely than the successful instruments	

Systems Engineering Thread #3: Requirements Changes

SE-3 Thread: Issues with Requirements Changes		
Area	**Issue**	**Correlation**
		Design Deficiencies
Requirements Changes	Design, requirements, or interface changes occurred after PDR (75%-IS, 45%-GWS) Note: ~60% of the instruments reported that requirements were defined and approved prior to PDR.	1.8x
Requirements Changes	Design, requirements, or interface changes occurred after CDR (50%-IS)	1.8x
	59% of the challenged instruments reported this as a problem	1.4x more likely than successful instruments

Systems Engineering Thread #4: Risk Management

SE-4 Thread: Risk Management Resource Issues			
Area	**Issue**	**Correlation**	
		≥25% Cost Overrun	**≥5 Months Schedule Delay**
Risk Management	Lacked resources to analyze identified risks (50%-IS)	1.6x	1.8x
	55% of the challenged instruments reported this as a problem	5x more likely than successful instruments	
Risk Management	Lacked resources to implement mitigation plans (65%-IS)	1.6x	1.4x
	55% of the challenged instruments reported this as a problem	5x more likely than successful instruments	
Risk Management	Risks were not identified regularly (38%-IS)	1.2x	1.9x
	Mitigation plans were not developed for all known risks (46%-IS)	1.2x	1.3x

Systems Engineering Thread #5: Review Effectiveness

SE-5 Thread: Effectiveness of Reviews			
Area	**Issue**	**Correlation**	
		≥25% Cost Overrun	**≥5 Months Schedule Delay**
Reviews	Peer Reviews viewed as very helpful (80%-IS)	Although there are no correlations noted, these issues provide insight into the perceived value of formal and informal reviews.	
	Test Reviews viewed as very helpful (52%-IS)		
	Requirements Reviews not viewed as helpful (23%-IS) (27% did not conduct formal requirements reviews; 57% did not conduct requirements reviews at the subsystem level)		
	Design Reviews not viewed as helpful (27%-IS)		
	Objectives not met in design reviews (53%-GWS)		
	Objectives not met in requirements reviews (32%-GWS)		

Instrument Management Theme

- Issues with Instrument Reserves
- External Factors
- Issues with Lines of Communication/Authority
- Issues with Schedule/Budget Management

Instrument Management Thread #1: Instrument Reserves

IM-1 Thread: Issues with Instrument Reserves			
Area	**Issue**	**Impact**	
		≥25% Cost Overrun	**≥5 Months Schedule Delay**
Cost/Schedule Reserve Authority	Lack of cost/schedule reserve authority at the instrument level (project held all reserves) (50% - IS)	1.4x	1.3x
	Less than 20% planned for budget reserves (40% - IS)	1.1x	2.0x

Instrument Management Thread #2: External Factors

IM-2 Thread: External Factors			
Area	**Issue**	**Correlation**	
		≥25% Cost Overrun	**≥5 Months Schedule Delay**
External Factors	Externally directed schedule changes (56%-IS)	1.5x	1.2x
	55% of challenged instruments reported this as a problem	4.2x more likely than successful instruments	
External Factors	Changes in budget allocation or phasing (39%-IS)	1.3x	2.0x
	50% of challenged instruments reported this as a problem	4.5x more likely than successful instruments	
External Factors	Incremental funding caused schedule delays or work stoppage (39%-IS)	1.3x	1.7x
	45% of challenged instruments reported this as a problem	4.1x more likely than successful instruments	

Instrument Management Thread #3: Lines of Communication/Authority

IM-3 Thread: Issues with Lines of Communication/Authority			
Area	**Issue**	**Correlation**	
		≥25% Cost Overrun	**≥5 Months Schedule Delay**
Organizational Interfaces	Lines of communication issues (57% - IS)	1.2x	2.3x
	70% of challenged instruments reported this as a problem	2.1x more likely than successful instruments	
Organizational Interfaces	Lines of authority issues (54% - IS)	NCN	1.7x

Instrument Management Thread #4: Schedule/Budget Management

IM-4 Thread: Issues with Schedule/Budget Management			
Area	**Issue**	**Correlation**	
		≥25% Cost Overrun	**≥5 Months Schedule Delay**
Subsystem Management	Schedules not managed well at subsystem level (67%-IS)	1.2x	1.6x
	70% of challenged instruments reported this as a problem	1.8x more likely than successful instruments	
Subsystem Management	Budgets not managed well at subsystem level (65%-IS)	1.4x	1.7x
	65% of challenged instruments reported this as a problem	3.0x more likely than successful instruments	
Subsystem Management	Not enough schedule ownership at subsystem level (61%-IS)	1.7x	1.4x
	75% of challenged instruments reported this as a problem	2.0x more likely than successful instruments	
Subsystem Management	Not enough budget ownership at subsystem level (52%-IS)	1.4x	1.7x

Systems Engineering Thread #4: Risk Management

SE-4 Thread: Risk Management Resource Issues			
Area	**Issue**	**Correlation**	
		≥25% Cost Overrun	**≥5 Months Schedule Delay**
Risk Management	Lacked resources to analyze identified risks (50%-IS)	1.6x	1.8x
	55% of the challenged instruments reported this as a problem	5x more likely than successful instruments	
Risk Management	Lacked resources to implement mitigation plans (65%-IS)	1.6x	1.4x
	55% of the challenged instruments reported this as a problem	5x more likely than successful instruments	
Risk Management	Risks were not identified regularly (38%-IS)	1.2x	1.9x
	Mitigation plans were not developed for all known risks (46%-IS)	1.2x	1.3x

Study – The Bottom Line

- This Study clearly shows that there are global challenges that impact the capability to design and build quality instruments
- Impact on Success Indicators
  - Cost Performance: ~70% of the instruments reported ≥25% cost overruns
  - Schedule Performance: ~60% of the instruments reported ≥5 months schedule delay
  - Technical Performance:
    - ~60% of the instruments reported design deficiencies that contributed to cost growth or schedule delays
    - ~80% of the instruments reported workmanship issues that contributed to cost growth or schedule delays
- Solutions
  - ✓ 5 Findings and associated Recommendations

Summary of Recommendations By Type

Type of Recommendation	Number of Recommendations
Policy/Process	14
Investment	9
Training	2
Awareness	4

Findings and Recommendations

Looking across the Study Themes

FINDING 1: Instrument developments lack the resources and authority to successfully manage to cost and schedule requirements.

RECOMMENDATIONS:

1. Implement changes to policy to define and elevate instrument management requirements and authorities in a manner similar to project-level management. (Policy/Process)
2. Assign NASA instrument managers full authority and responsibility to manage their cost and schedule reserves and hold them accountable. (Policy/Process)
3. Require 30% to 50% cost reserves for instrument developments (>$10M) to account for the fact that most instrument developments are highly complex, single builds. (Policy/Process, Investment)
4. Require 1½ to 2 months per year of schedule reserve for instrument developments (>$10M) . (Policy/Process, Investment)
5. Require dedicated level of support staff (configuration management, schedule management, risk management and budget management) for instrument developments (>$10M) . (Policy/Process, Investment)

FINDING 2: Instrument developments are lacking the critical skills, expertise, or leadership to successfully implement these unique (one-of-a-kind), high technology developments.

RECOMMENDATIONS:

1. Expedite the planned enhancement of the NASA Engineering Network People, Organization, Project, Skills (POPS) expertise locator to enable instruments to address critical skills shortages by drawing upon personnel from other NASA centers. (Awareness)
2. Add capability to the POPS locator to include data sources external to the NASA workforce. (Investment)
3. Require the addition of a deputy instrument manager position (similar to a deputy project manager), for instrument developments with a budget >$10M. (Policy, Investment)

Note: The survey results also indicated broader issues with staffing that relate to attracting and retaining critical skills or expertise. These issues are being otherwise addressed by the NASA National Recruitment Initiative.

FINDING 3: There are significant process problems in the area of requirements formulation, reviews, and management.

RECOMMENDATIONS:

1. Require NASA instrument team leadership to take requirements formulation/management training, e.g., "Requirements Development and Management (APPEL-REQ)", prior to requirements development. (Training)
2. Require instrument teams to conduct Peer Reviews of requirements (for each instrument subsystem), in preparation for instrument SRRs. (Policy/Process)
3. Require draft mission Level 1 and 2 technical requirements to be controlled and provided to instrument managers prior to the instrument SRR. Also, notify instrument managers of any changes to the draft requirements so that impact assessments can be performed. (Policy/Process)

FINDING 4: **Unrealistic caps, overly optimistic estimating, and externally directed changes correspond to a significant increase in the likelihood of overrunning cost and schedule.**

RECOMMENDATIONS:

1. **Develop an Agency-level historical cost and schedule database of instruments to provide information that would allow for higher fidelity cost caps. (Investment)**
2. **Review cost credibility evaluation and scoring criteria for accuracy and flow-down to the proposal selection process (for use by Technical Management and Cost (TMC) or project Source Evaluation Board (SEB)). (Process)**
3. **Establish a Peer Review prior to PDR for instruments >$10M to assess budget and schedule baseline credibility and increase the emphasis on cost and schedule assessment at PDR. (Policy/Process, Awareness)**
4. **Ensure that instrument managers are made aware of externally driven changes in a timely manner and afforded the opportunity to discuss any impacts prior to implementation of changes. (Process, Awareness)**

Note: The NICS team did not develop a recommendation for cost estimating problems since this issue is currently being addressed by a multi-Agency team (The Space Systems Cost Analysis Group, co-chaired by NASA). This group is sponsoring a Baseline Realism Team.

FINDING 5: NASA needs a method to continue answering basic questions pertaining to the instrument development process to identify any emerging or persisting issues.

RECOMMENDATIONS:

1. **Require *all* instrument managers to take the survey upon delivery of their instrument. (Policy, Investment)**
2. **Maintain survey results in a historical database. (Policy, Investment)**

Path Forward

Based on the 5 Findings, the Study team determined that NASA needs a focus on instrument development at the Agency level.

RECOMMENDATION:

1. Establish a strategic instrument capability alliance dedicated to improving the capability to design and build quality instruments within cost and schedule constraints. (Policy/Process, Investment, Training, and Awareness)
   a. Collaborative effort to provide a framework for improving instrument development processes.
   b. Participation from NASA, NOAA, DoD, industry, and academia.
   c. Support implementation of Study recommendations.
   d. Revise the existing Study surveys based upon lessons learned.
   e. Develop and maintain a tri-Agency instrument survey data repository.